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Original Research

Effect of Caudal Traction on Mechanical Nociceptive Thresholds of Epaxial and Pelvic Musculature on a Group of Horses With Signs of Back Pain

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A B S T R A C T

Direct muscular attachment from lumbar vertebrae to the caudal vertebrae of the tail suggests that caudal traction, also described as a tail pull, may affect lumbar vertebral segments and/or associated soft tissues in horses. Traction is a commonly used human manual therapy technique used for pain relief and anecdotally observed to relieve pain in horses. However, research is lacking validating the efficacy of manual caudal traction on the horse. The objective of this study was to determine if caudal traction has an effect on mechanical nociceptive thresholds (MNTs) in a group of horses with clinical signs of back pain. Pressure algometry was used to measure MNTs of five bilateral anatomical sites in the epaxial and pelvic musculature of 11 horses referred to physiotherapy because of clinical signs of back pain. Measurements were recorded both before and immediately after traction. A significant difference ($P \leq .05$) was identified between mean before and after caudal traction algometry measurements in all described sites. The percentage of MNT increase was highest in the thoracic region (83%) compared with the lumbar (50%) and the pelvic (52.4%) regions. These results support an effect of caudal traction in increasing MNTs in the thoracolumbar and pelvic regions in horses. Further research to determine the clinical effect of this technique is warranted.

1. Introduction

Equine back pain is recognized as a common cause of poor performance in riding horses across all disciplines [1,2]. Manual therapy techniques used to treat human back pain have evidence to support their use [3,4]. However, despite various manual techniques being used to treat equine back pain, most have not been scientifically evaluated for efficacy in relieving pain or musculoskeletal dysfunction. Caudal traction, also described as a tail pull, typifies a manual therapy treatment with only anecdotal evidence to support its use.

In human clinical practice, traction has been described since the Hippocratic era and continues to be a commonly used manual therapy technique [5–7]. Grades of manual force, achieving speculated joint separation and effect are described [8]. Grade one neutralizes joint pressure without separation of joint surfaces, grade two separates articulating surfaces eliminating joint play within the joint capsule, whereas grades three and four stretch soft tissue and surrounding joint structures [9]. Historically, traction is used for relief of pain, for normalization of neurological deficits, and for improving joint mobility [10–12]. In addition, the central nervous system receives input from changes in length, tension, and rate of change in neuromuscular structures including proprioceptors, muscle spindles, and golgi tendon organs, triggering a cascade of neurophysiological responses [13,14]. Despite this, more recently, a review by Mitchell et al. (2017) concluded surprisingly little is known about the physiological effects of traction [15].

Animal welfare/Ethical statement: Where applicable, the methodology of our study met the International Guiding Principles for Biomedical Research Involving Animals as issued by the Council for the International Organizations of Medical Sciences. As stated in the materials and methods section of our manuscript, ethical approval from the University of Liverpool (Ref: VREC779, March 2019) was received, as was consent from the included horses' owners. Because of caudal traction being used on clinical cases where this was part of their standard treatment, no approval was required from the New Zealand Animal Ethics Committee.

Conflict of interest statement: The authors do not have any conflicts of interest to declare.

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The size and quadruped stature of the horse may not allow similar biomechanical response to caudal traction as seen in the biped human population; however, because of muscular and fascial attachments, it is possible that application of traction via the tail could have a reaction in surrounding tissues. In the horse, muscular attachment of lumbar vertebrae to the caudal vertebrae of the tail indicates that manual traction of the caudal vertebrae could have an effect on lumbar vertebral segments or associated soft tissues. Research by Stubbs et al. (2006) observed the sacrocaudalis dorsalis lateralis (SCDL) muscle or lateral tail head muscle to be an extension of multifidus from lumbar vertebrae (L) 4, 5, and 6 inserting onto caudal vertebrae [16]. Bursae associated with SCDL imply notable force and motion coupled with it, indicating the muscle function is greater than simply tail movement. In addition, the type IIA fibers of SCDL suggest dual functionality, that is, tail movement and neuromuscular stabilization of the lumbosacral and caudal vertebral region [17]. Therefore, theoretically, the tail could be used to influence the structures of the lumbar spine, a common site for equine back pain [18].

The aim of this study was to examine the effect of caudal traction on equine thoracolumbar mechanical nociceptive threshold (MNT) measurements. We hypothesized that caudal traction would significantly increase the MNT in pelvic and thoracolumbar musculature of horses with signs of thoracolumbar pain.

2. Materials and Methods

Prior to commencing the study, a pilot study of 32 horses was conducted to test and confirm the achievability of the planned protocol described in the following and to confirm the appropriate, standardized force to be used in a tail pull.

2.1. Horses

Horses with veterinary referral for thoracolumbar back pain, grade 0–2 lameness [19], and for which caudal traction was considered appropriate after physiotherapy assessment were included in this study. Exclusion criteria were horses with neurological issues or horses that resented handling of the tail or their hind quarters. The data collection was conducted in New Zealand by one of the authors (K.L.). Ethical approval from the University of Liverpool (Ref: VREC779, March 2019) was received as was consent from the horse owners. Because of caudal traction being used on clinical cases where this was part of their standard treatment, no approval was required from the New Zealand Animal Ethics Committee.

Horses were seen in their home stable, stood square on a flat surface and held with their neck in line with their back by their owner. Five bilateral thoracolumbar locations, as previously described by Haussler and Erb (Table 1) [20], were identified and marked on each horse bilaterally with correction fluid (Fig. 1). All measurements of these points were taken in the order of cranial to caudal, medial to lateral. A calibrated pressure algometer (JTECH Medical Commander, UT, USA) with a 1 cm^2 rubber tip was used to measure MNTs from the marked locations by a single examiner who was an experienced manual and animal physiotherapist (K.L.). The measurer was blinded to the results of the algometer reading by turning the algometer away from the measurer during the measurement. The algometer was applied at a constant speed, at a 90-degree angle, and pressure was stopped immediately on identification of a recognized behavioral response. An equine behaviorist assisted with identifying the equine reaction. Reactions resulting in the cessation of the algometer application included the ‘pain face’ response (tense stare, low or asymmetrical ears, nostrils dilated, or facial muscle tenseness) as described by Gleerup et al. [21] and signs like fasciculation, eyes wide, ears back, moving away, or tail swishing. Once a response was observed, the algometer was passed to a third party to record the results. To increase reliability, three measurements were recorded for each site, with the mean of these measurements used for statistical analysis. A 10 second interval between each recording was allowed to limit adaptation or sensitization to the measurement, that is, three measurements per each point were performed with 10 second intervals between each measurement. Thus, each horse took 5 minutes to measure. Each treatment took 1.5 minutes, after which the measurements were

Table 1
Anatomical locations of specified points for algometry measurements.

Site Number	Anatomical Location
1	The longissimus dorsi thoracis at T 18 vertebral level, 2 cm lateral to midline (LDT18,2)
2	The longissimus dorsi thoracis at T18 vertebral level, 10 cm lateral to midline (LDT18,10)
3	The middle gluteal muscle at L3 vertebral level, 10 cm lateral to midline (MGL3)
4	The middle gluteal muscle at midpoint between tuber sacrale and tuber coxae (MGTS/TC)
5	Vertebral head of the biceps femoris, 20 cm dorsal to the greater trochanter (VHBF)

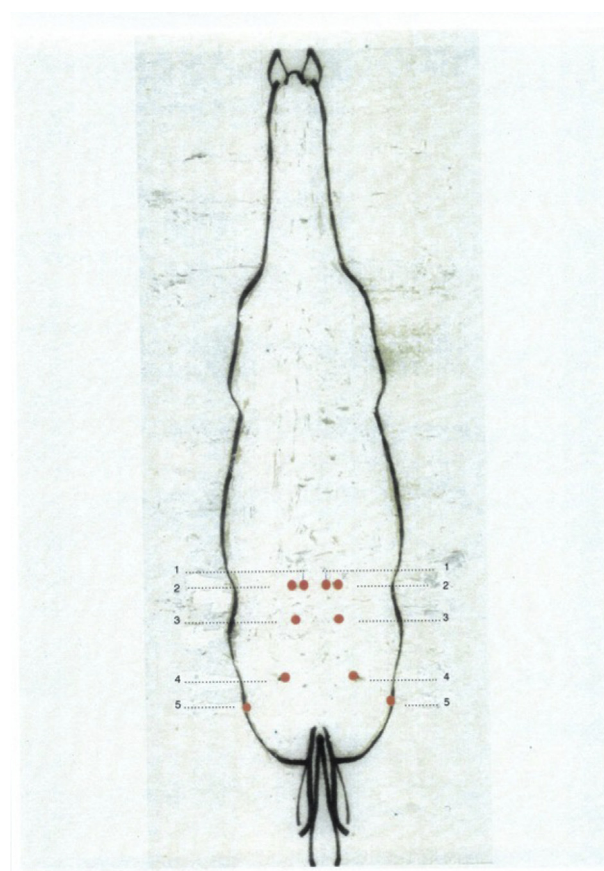

Fig. 1. Locations of anatomical landmarks of the five mechanical nociceptive threshold (MNT) measurement sites, numbered 1–5 (not drawn to scale): 1 = the longissimus dorsi thoracis at T 18 vertebral level, 2 cm lateral to midline, 2 = the longissimus dorsi thoracis at T18 vertebral level, 10 cm lateral to midline, 3 = the middle gluteal muscle at L3 vertebral level, 10 cm lateral to midline, 4 = the middle gluteal muscle at midpoint between the tuber sacrale and the tuber coxae, 5 = vertebral head of the biceps femoris, 20 cm dorsal to the greater trochanter.

repeated. Hence, each point was measured with at least 6.5 minutes between measurement sets.

A clinometer bubble level was strapped to the tail to ensure the therapist pulled at a consistent angle of 30° from horizontal, in the line of the sacrum of the horse. A digital fish scale was hooked through the plaited tail and a steady pull of 4.5 kg was applied for 20 seconds followed by a 10 second release, repeated for three sets (Fig. 2). Algometry measurements were repeated immediately after traction. The left side was always measured first, and the order of sites measured never changed. After the data collection, each horse then received the remainder of their routine physiotherapy treatment.

2.2. Statistical Analysis

Statistical data were analyzed using SPSS, version 24, software (IBM SPSS Statistics for Macintosh, Version 24.0). Data were tested for normality using the Kolmogorov–Smirnov test. Results indicated some data were distributed normally and some non-normally. Because of non-normal distribution and the small sample size, the Wilcoxon signed-rank test was selected for data analysis. The level of significance was set at $P \leq .05$. The effect size across the group was analyzed by using the Kendall's coefficient of concordance. The results were interpreted in accordance with the Cohen's interpretation guidelines, whereby 0.1 would be the limit for small, 0.3 for moderate, and 0.5 for strong effect. Effect size for the individual measurement point differences was analyzed by confidence interval, with related-samples Hodges-Lehman median difference analysis. A general linear model was used to calculate the effect of age, height, gender, and breed.

3. Results

A total of 11 horses, two mares and nine geldings were included in this study. The breeds comprised four Warmbloods, four Thoroughbred crosses, two Quarter Horses, and one Appaloosa. The median age was 16.8 years with a range of 6–29 years, and the median height was 158 cm (range 152–166 cm). Six horses on veterinary assessment had grade one out of five lameness, and five horses had grade two out of five lameness [19]. Based on the veterinarians' referrals, the clinical signs of back pain were considered to be acute in all the horses except one. None of the horses had received physiotherapy treatment for their current signs of back pain before attending the study. The initial physiotherapy assessment identified active trigger points within longissimus dorsi and middle gluteal muscles of all horses in this sample. The general linear model indicated that age, height, gender, or breed of the horse did not have a significant effect on results. Consistent weather provided stable ambient temperature with less than half a degree Celsius in change of temperature for the duration of the study. All horses were seen between 9 AM and 2 PM.

Behavioral indications to cease application of algometer pressure at T18, both 2 cm and 10 cm lateral from midline, as well as at L3 level, were either fasciculation (n = 7) or eyes wide and ears back (n = 3) responses. One horse only widened its eyes. At the gluteal muscle and vertebral head of biceps, some horses moved away (n = 7 and n = 8, respectively) and others swished the tail (n = 4 and n = 3, respectively).

The difference between algometer measurements before and after caudal traction is displayed in Table 2. There was no significant mean difference between left and right sides, and results were pooled for each measurement point presented in Fig. 1. The Kendall's coefficient of concordance for the whole group pooled was 0.474, showing a strong effect. The individual measurement point effect sizes are presented in Table 2.

4. Discussion

The hypothesis that there would be an increase in the MNT after caudal traction at all sites measured was supported by our results. It was noted that all regions did not react to the caudal traction equally; the percentage of improvement was highest in the thoracic region at 83% with the lowest percentage of improvement in the lumbar region, still indicating a 50% increase in the MNT. The pelvic region responded with 52.4% change between before and after

Fig. 2. Equipment needed and technique used to perform the study. 2a) Equipment used: the JTECH Commander pressure algometer (A), clinical bubble level app (B), 'Wite-Out' correction fluid (C), and digital fish scale (D). 2b) Example of caudal traction setup.

Table 2
Median MNT value (N/cm^2) before traction and after traction on the left and right side of the spine.

Site		Before Traction (N)	After Traction (N)	Statistical Significance of the Difference	An Estimate of the Effect Size
(LDT18,2) left	Median	8.1	20	$P = .003$	12.1
	IQR	5.2	8.7		
	95% CI	7.4–10.9	18.0–24.9		
(LDT18,2) right	Median	8.5	22.2	$P = .003$	9.7
	IQR	8.6	9.0		
	95% CI	7.4–12.9	19.6–26.1		
(LDT18,10) left	Median	9.5	23.5	$P = .003$	9.1
	IQR	4.8	7.6		
	95% CI	8.3–13.2	20.5–27.2		
(LDT18,10) right	Median	11.4	23.5	$P = .003$	13.0
	IQR	6.2	7.3		
	95% CI	8.4–13.9	21.4–27.3		
(MGL3) left	Median	10.4	28.1	$P = .003$	16.6
	IQR	3.1	7.9		
	95% CI	7.8–15.6	25.3–30.9		
(MGL3) right	Median	10.7	27.2	$P = .003$	13.9
	IQR	6.1	7.6		
	95% CI	8.6–15.9	23.1–29.3		
(MGTS/TC) left	Median	13.2	30.9	$P = .008$	12.9
	IQR	16.8	2.7		
	95% CI	11–22.4	27.4–31.9		
(MGTS/TC) right	Median	17.6	29.8	$P = .003$	8.7
	IQR	14.7	7.3		
	95% CI	14.2–23.0	24.8–31.2		
(VHBF) left	Median	16.1	31.3	$P = .005$	10.7
	IQR	17.5	3.4		
	95% CI	13.7–25.1	28.5–32.6		
(VHBF) right	Median	24.2	32.3	$P = .003$	9.7
	IQR	15.5	2		
	95% CI	17.0–27.3	31.2–33.0		

CI, confidence interval; IQR, interquartile range; MNT, mechanical nociceptive threshold.

caudal traction readings. As well as the significant difference between the measurements before and after the caudal traction, the effect size between the pre- and post-measures was strong. Moreover, the estimates of effect sizes in all individual measurement points were very high.

Supporting the findings of the present study, previous publications have also noted that the horses' MNT algometer readings increased from cranial to caudal regions [20,22–24]. It is thought that regional variation in MNTs may be the result of increased local nociceptor density, increased pain pathway lengths, or due to change in tissue density with increasing fascial thickness craniocaudally [24–27]. Haussler and Erb noted higher MNTs measured in castrated male, non-Thoroughbred breeds [20], whereas De Heus et al. (2010) recorded lower MNT values in their sample of six Warmbloods [23] than we did in our study. Our study did not observe any difference between MNT and sex or breed; this may have been due to sample size or that the Thoroughbreds used in this study were not purebred.

There are several factors leading to individuality in pain thresholds. Neogi et al. (2015) verified pain pressure thresholds are associated with pain severity [28]. A review of 42 studies identified different responses to acute and chronic pain compared between various cultural groups [29]. More recently, Petersson and Abbott (2020) found in a group of healthy young men and women that posture significantly affected pain threshold values [30], indicating the importance of test positioning of horses in study groups. A study on six healthy warmblood horses recorded a significant difference in MNT measurement between individual horses [23]. This concurred with a study conducted by Wang-Price et al. (2019), who found significant variation in pain threshold testing in muscles tested in clients both with and without pain [31]. Individual variation in response to sensory stimulation has also been found greater in women than that in men [32].

The superficial dorsal fascial line has been described as originating from the medial hind limb phalanx, extending up the hind limb, radiating into the epaxial muscles (m. spinalis, m. longissimus dorsi, and m. iliocostalis) along the thoracic region to the occiput, mandible, and m. masseter [33]. Thus, the fascial structures can also transfer the effect of caudal traction further to the structures of the more cranial parts of the body. Silva et al (2018) consider the reestablishment of the sliding system achieved with fascial release may inhibit nociception due to the fascia's high innervation of autonomic fibers [34]. Therefore, it may be that the caudal pull causes the horse to use its head and neck as a counterweight, leaning against the pull, thus stretching the epaxial muscles, resulting in relaxation of the muscles. Static muscle stretching can be described as elongation of the muscle with application of low force and long duration (usually 30 seconds), which is akin to our described technique [35]. Benefits include an inhibitory effect from the golgi-tendon organ, causing decreased neuron excitability and decreased sensitivity of nociceptors [36].

In this study, the mechanical effect of traction on the joints was not measured. However, it is unlikely that the 4.5 kg pulling force would cause a mechanical separation in joints in, for example, the thoracic area, where most effect to the MNT was seen. Rather, we assume the caudal traction to be more generic in its effects in relation to the equine spine. The increase in the MNT seen in the thoracic region in this study implies a tail pull has a greater effect on muscular and/or fascial tissues (as opposed to joints) in the horse, hence the greater response in the thoracic region. Response to manual therapy techniques performed in previous human research has been identified in areas distant to the actual site of technique application, for example, manual therapy to the thoracic spine instantly relieved mechanical pain in the cervical spine [37]. This model would be consistent with the small 4.5 kg traction that was used to apply the technique.

The reasons for the treatment effect might lie not only in the mechanical traction effect on the spinal joints, or in the fascial and muscle tissues, but also in the neural system. Bialosky et al (2009) suggest in addition to biomechanical mechanisms, a sequence of neurophysiological responses are initiated after mechanical force application possibly including peripheral, spinal cord, or supraspinal mechanisms [14]. Tail pull traction could affect the horses' inflammatory mediators and peripheral nociceptors directly, or it could exert a direct effect on the spinal cord via bombardment with sensory input from muscle proprioceptors initiating a spinal mechanism [38]. Answers to these questions are beyond the scope of this study; however, the results of this study support a far-reaching effect from the site of treatment application and a decreased nociception in the areas tested.

Only relative values were considered for each horse rather than drawing a comparison between horses as this was a sample of horses with signs of thoracolumbar pain. Haussler and Erb consider the potential use of comparing contralateral MNT values in unilateral pathology [20], but there was no significant difference in results between left and right sides in our sample population. This might be due to the above mentioned possible general tissue effect, but also due to the fact that the caudal traction was carried out in midline, thus affecting tissues bilaterally. In addition, again, the individuality of subjects with reference to pain thresholds may be one factor. Grieve et al. (2013) observed trigger point location can vary within the entire body [39]. Although this study selected sites used by previous equine studies for pressure algometer measurement, the presence of trigger point activity could elicit variation in nociceptive recordings [40].

It could be argued that repeated algometer measurements produce a trigger point response that has its own treatment effect, thus affecting our results. Sullivan et al. (2008) previously demonstrated a lack of adaptation to the procedure on a group of healthy horses exhibiting no clinical signs of back pain [41]; however, this is not to say this is true for a group of horses with signs of back pain as initial physiotherapy assessment of these horses identified active trigger points within longissimus dorsi and middle gluteal of all horses in this sample. The initial MNT readings found in this study, when converted from Newtons to kg/cm^2 for comparison purposes, were between 9.8 and 12.8 kg/cm^2, lower than regional expected thresholds described by Haussler and Erb [20]. This could be explained by our sample having signs of thoracolumbar pain in contrast to their healthy horses. An earlier study indicated horses with documented musculoskeletal injuries displayed MNTs in the affected areas often $\leq$5 kg/cm^2 which concurs with our findings [42]. Algometry measurements by Varcoe-Cocks et al. [22] on a group of racing Thoroughbreds with suspected sacroiliac dysfunction were significantly higher than our findings. Cases of sacroiliac dysfunction classified as severe had a mean algometry measurement of 30 N/cm^2 (3.06 kg/cm^2 equivalent). In comparison, our highest MNT result was 31.3 N/cm^2 (3.2 kg/cm^2 equivalent) achieved after treatment, with the pretreatment lower range at 9.7 N/cm^2 (0.99 kg/cm^2 equivalent). Their sample population was very different from the present study in terms of breed, activity, and age, and those factors may be the reason to the differences between our values. That being said, more likely reason for the differing results may be a possible difference in measurement technique. In the previous study, the speed on measurement was not reported, whereas we used a constant speed when performing the measurement. If the speed of measurement was not constant, it may have caused the horses of the previous study to react differently, than what the horses in our study did.

Pressure algometry was selected as an outcome measure for our study as research has indicated it to be a useful tool to objectively evaluate treatment results and for quantifying musculoskeletal pain [22,23]. Examiner competence, inter-rater reliability, rate of application, and tip selection have been recognized as influential on accuracy of pressure algometry measurement [20,22–24,43,44]. Accordingly, in our study, one experienced examiner (K.L.) conducted all testing with a constant rate of perpendicular application at 1 kg/second, using a 1 cm^2 rubber tip. The horse was held in the same position for marking as when to be tested to counter the elastic nature of skin and minimize shifting of the marked sites. A fixed order protocol was adopted to reduce variability. Although most responses signaling cessation of application of algometry pressure were easily assessed by the examiner, standing at the hind end of the horse did not allow the examiner easy identification of facial response of the horse in response to the applied pressure algometer. For this reason, an equine behaviorist was also present to report when the horse showed the more subtle 'pain face' response. The pressure algometer was easy to use and tolerated well by the subjects.

Stress, fear, and anxiety are recognized to alter perceived levels of noxious stimuli or possibly initiate opiate-related analgesia, so testing was conducted in the horses' own quiet, relaxed home environment with restraint provided by the owner [45,46]. Our stable ambient temperature (17°C +/− 0.5°) provided very little variation. A study by Grint et al. (2014) manipulated ambient temperature on a group of donkeys in a laboratory environment [47]. They concluded that their temperature range between 23 and 27°C did not affect MNTs in comparison with an unpublished study they cite by Chambers [48], where ambient temperature increased MNTs in a group of sheep when the temperature was below 8°. As our remeasurement occurred approximately 5 minutes after the initial recordings, temperature fluctuation was unlikely to have a significant impact on this study, although it was recorded should it be useful for future reference.

This is the first study evaluating the effect of manual caudal traction on the horse. Therefore, parameters selected for this study were adopted from human prescription with the intent of repeatability and to form a foundation from which future research could develop. The 4.5 kg force of pull was selected as 4 kg force was the approximate minimum traction to elicit visual response of the hind limb musculature and met an 'end-feel' akin to human manual traction application and greater forces have not always indicated greater therapeutic effect [9,49]. In the pilot phase of the study, attempting to maintain a static 4 kg force was unsuccessful for horse compliance (they kept flicking their tail), whereas 4.5 kg was achievable and the horse settled well. Again, piloting showed horses' tolerance dictated 20 second holds with three repetitions which are similar to commonly used traction prescription in humans [50].

Although this study met its objectives in showing manual traction increased MNTs in the thoracolumbar and pelvic regions, we have not directly tested its therapeutic effect on its own. The human literature remains divided regarding therapeutic outcomes of manual traction techniques, with some guidelines supporting traction [51,52], whereas others found inconclusive evidence to support traction as beneficial [53,54]. Systematic reviews on traction for cervical pain disregard traction-related research based on poor research techniques, including bias and low population numbers [55,56]. Despite this, clinically observed positive outcomes see traction remains in the clinical environment and emerging high-quality research endeavors to validate its use [5,57]. Future research with larger numbers and with control groups will be required to test whether this effect on MNTs translates to a therapeutic effect in horses.

A limitation of our study was the lack of specific diagnosis of the pathological cause of the thoracolumbar pain in our horses with the exception of one horse, who after scintigraphy was diagnosed with right sacroiliac joint dysfunction. In addition, we did not specify the level or duration of pain. This may have affected our results as it could be assumed that not all pathologies and types of pain will respond well or equally to the treatment. If the results were skewed, it is expected they would be skewed in the direction of getting inferior results, rather than getting false positive results and potentially incurring error. The reality of treating horses with back pain is that often the nature of the back pain is not confirmed (primary or secondary), nor is a definite pathological diagnosis reached. Pathological lesions in the equine thoracolumbar region are highly prevalent and poorly correlated to clinical signs of pain [20,58]. Similarly, in humans, there is not necessarily a correlation between underlying pathology and lower back pain [59–61]. Nevertheless, the pain in the area needs to be diagnosed and treated.

Another limitation was that our study only assessed immediate and short-term results of this treatment technique. The horses included in this study were clinical patients with clinical signs of back pain, and the data were collected as part of their usual physiotherapy treatment. To comply with New Zealand ethics, nothing out of normal physiotherapy practice–related actions was allowed to be undertaken; thus, long-term measurements were not feasible, nor would a cross-over approach have been appropriate, albeit they would have provided more interesting data for this study. Nevertheless, even short-term effects are of value to provide short-term pain relief, allowing the therapist then to pursue other treatment techniques which may have been inhibited previously due to pain. Examiner bias was possible with a veterinary physiotherapist examining effectiveness of a physiotherapeutic technique. This was minimized by blinding the examiner to the algometry recordings and having the equine behaviorist confirming the horses' reactions to the pressure.

A major limitation to our study was that it did not include a control group. Having a control group, that is a group of horses without signs of back pain, might have helped to understand the level of thoracolumbar pressure sensitivity of our group of horses in comparison with the clinically normal ones. Moreover, we might have been able to gather more information regarding the effect of the caudal pull on normal and back pain horses and would have had more information about whether or not the algometer measurements themselves produced a trigger point response with its own treatment effect.

5. Conclusion

Based on the results of this study, caudal traction increased the MNTs in the thoracolumbar and pelvic musculature. Further research to determine the clinical effect of this technique is warranted.

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